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Realizations of Electromagnetic Pulsed-Beam Wavelets and Applications of Physics-Based Radar Analysis and Sensing

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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13. SUPPLEMENTARY NOTES

14. ABSTRACT
1. A solid and rigorous understanding of PBW sources has been established, though more work is needed to compute realizable current sources (eliminating magnetic charges).
2. New results on using branch cuts to form spheroidal antennas are promising, as they determine the necessary boundary conditions to make the sources nonsingular.
3. The recent computation of the 4D Fourier transform of PBW opens the way toward efficient numerical computations with PBW based on the FFT, including their implementations toward EM wavelet-based radar analysis.

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Gerald Kaiser
U	U	U	UU		19b. TELEPHONE NUMBER (Include area code) 804-262-5505

FINAL REPORT
15 March 2001 - 31 December 2003

GRANT TITLE:
Realizations of Electromagnetic Pulsed-Beam Wavelets and Applications of Physics-Based Radar Analysis and Sensing

AFOSR Grant # F49620-01-1-0271

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[List Co-PIs/Subcontractors, if any]
Subcontractors:

None.

OBJECTIVES
A. Original Objectives:

1. With guidance from Dr. Richard Albanese of AFRL/HEDB, examine the hardware realizability of electromagnetic pulsed-beam wavelets (PBW). In particular, pursue practical issues such as the efficiency, physical aperture, radiation resistance and impedance associated with physically realizable PBW sources.

2. Also with Dr. Albanese, study the feasability of using quantum effects in beamforming and imaging and their possible applications to the interrogation of closed metal containers that may contain chemical or biological agents.

3. Extend all results obtained previously from the scalar case (wave equation) to the vector case (Maxwell's equations), including the 4D Fourier representation and the physics-based radar analysis (PBRA). formal transformations (which could be used to focus the wavelets).

4. Using the explicit Fourier representation of PBW, apply the associated PBRA to accelerating and rotating targets and/or radar platforms. Use available Clifford-based computer codes to facilitate calculations in the EM case, possibly including polarimetry. Compare the results to the currently used ``motion compensation'' methods, which consist of dividing targets into small (point-like) cells and and performing a separate analysis on each cell.

B. Objective added during contract period:

5. Compute the equivalent surface sources (polarizations and charge-current density) on oblate spheroids necessary to realize PBW.

STATUS OF EFFORT
[A brief statement of progress towards achieving the research objectives. Please make this substantive (Limit to 200 words).]

1. Equivalent sources needed for realizing PBW on oblate spheroids were computed in several stages, but these were not completely satisfactory because the proper boundary conditions were only discovered recently (January 2004), as explained in a just-completed report (Making Electromagnetic Wavelets, http://arxiv.org/abs/math-ph/0402006).

2. I studied various ways of attempting detection of chemical or biological agents, including neutron scattering, Raman scattering, and geometric phases. My original impression that quantum effects were too weak to be practical outside of laboratory conditions were confirmed by many prominent authorities in experimental quantum physics. Of the possible methods surveyed, Raman scattering seems to be the most promising.

3. The goal of computing the 4D (space-time) Fourier transforms of EM
wavelets was fully realized in my Topical Review article (Journal of Physics A, http://www.iop.org/EJ/toc/0305-4470/36/30). The Fourier transform turned out to have a very simple and compact form, which bodes well for its practical applications.

ACCOMPLISHMENTS/NEW FINDINGS
[Describe research highlights, their significance to the field, their relationship to the original goals, their relevance to the AF's mission,
and their potential applications to AF and civilian technology challenges.]

1. A solid and rigorous understanding of PBW sources has been established, though more work is needed to compute realizable current sources (eliminating magnetic charges).

2. New results on using branch cuts to form spheroidal antennas are promising, as they determine the necessary boundary conditions to make the sources nonsingular.

3. The recent computation of the 4D Fourier transform of PBW opens the
way toward efficient numerical computations with PBW based on the FFT, including their implementations toward EM wavelet-based radar analysis.

PERSONNEL SUPPORTED
[List professional personnel supported by and/or associated with the research effort.]

1. Professor Iwo Bialynicki-Birula
   Center for Theoretical Physics
   Al. Lotnikow 32/46
   02-668 Warszawa, Poland
   Consulting in electromagnetic theory
   50 hours, June 10-20, 2003.

2. Dr. Simonetta Frittelli
   493 Woodland Rd.
   Pittsburgh, PA 15237

Consulting on Electromagnetic Wavelets
120 hours, May 1- 28, 2003.

3. David Park
5605 West Falls Road
Mount Airy, MD 21771
Mathematica programming & graphics consulting
Total of 40 hours during 2003.

PUBLICATIONS
[List peer-reviewed publications submitted and/or accepted during the 12-month period starting the previous 1 August (or since start for new grants).]

1. G. Kaiser, Communication via Holomorphic Green Functions.
Invited paper, NATO Advanced Research Workshop on Clifford Analysis and its Applications.
In "Clifford Analysis and its Applications", edited by F. Brackx, J.S.R. Chisholm and V. Soucek
Kluwer NATO Science Series, 2001. http://arxiv.org/abs/math-ph/0108006

2. G. Kaiser, Complex-distance potential theory, wave equations, and physical wavelets.
Invited paper, Special Issue on Clifford Analysis in Applications, F. Sommen and W. Sproessig, Editors.
Mathematical Methods in the Applied Sciences 25:1577-1588, 2002

3. G. Kaiser, Physical wavelets and their sources: Real physics in complex spacetime.
Topical Review, Journal of Physics A: Mathematical and General Vol. 36, Nr. 30, R291-R338, 2003.
http://www.iop.org/EJ/toc/0305-4470/36/30

4. G. Kaiser, Helicity, polarization, and Riemann-Silberstein vortices.
To appear in Journal of Optics A, Special Issue on Singular Optics, May 2004.

BOOK IN PREPARATION:
"Physical Wavelets and Wave Equations," under contract for Progress in Mathematical Physics book series, Birkhauser-Boston.

INTERACTIONS/TRANSITIONS
Participation/Presentations At Meetings, Conferences, Seminars, Etc.
[Be selective, but be sure to include participations that reflect the quality/impact of the effort]

A. Conferences:

1. Distributional sources for Newman's holomorphic Coulomb field.
Invited paper, Workshop on Canonical and Quantum Gravity III, Banach Cente
Polish Academy of Sciences, Warsaw, June 7-19, 2001.
http://arxiv.org/abs/gr-qc/0108041

2. Electromagnetic wavelets as Hertzian pulsed beams in complex spacetime.

Plenary paper, Topics in Mathematical Physics, General Relativity and Cosmology.
Mexico City, September 17-20, 2002. To be published by World Scientific Press.

3. Making Pulsed Beams. Invited lecture, Workshop on Multiscale Geometric Analysis:
Theory, Tools, and Applications Institute for Pure and Applied Mathematics, UCLA, January 13-17, 2003.
http://www.ipam.ucla.edu/programs/mga2003/mga2003_schedule.html

4. Secrets of complex-source pulsed beams: Spacetime and Fourier source
distributions.
Singular Optics 2003, NATO Advanced Research Workshop, Kiev, Ukraine, June 24-29, 2003.

5. Realization of EM Wavelet Radar, Tutorial lecture.
Noise Radar Technology Conference, KharkovUkraine, October 21-23, 2003.

B. Seminars:

1. Complex-Distance Potential Theory, Wave Equations, and Physical Wavelets.
Mathematics Department, University of Texas-Dallas, November 27, 2001

2. Introduction to Physical Wavelets. Physics Department, University of
Pittsburgh, August 4, 2001

3. Distributional Sources for Newman's Holomorphic Electromagnetic Fields.
Mathematics Department, University of Algarve, Portugal, June 28, 2001

4. Distributional Sources for Newman's Holomorphic Coulomb Field.
Mathematics Department, Case-Western Reserve University, May 3, 2001

5. The secret lives of complex-source pulsed beams: Their source distributions in the Spacetime
and Fourier domains Boston University Center for Computational Science Seminar, April 15, 2003

* Consultative And Advisory Functions To Other Laboratories And Agencies
[Consultative and advisory functions to other laboratories and agencies,
especially Air Force and other DoD laboratories. Provide factual information about the subject matter, institutions, locations, dates, and name(s) of principal individuals involved.]

NEW DISCOVERIES, INVENTIONS, OR PATENT DISCLOSURES
[If none, report None.]

None.